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Abstract

Hydrodynamic Instability and Dynamic Burnout in Natural Circulation Two-Phase Flow. An Experimental and Theoretical Study.

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A theoretical model for predicting the threshold of instability for two-phase flow in a natural circulation loop is presented. The model calculates the flow transient caused by a step disturbance of the heat input, and is based upon the conservation laws of mass, momentum and energy in one-dimensional form. Empirical correlations are used in the model for estimating the void fractions and the two-phase flow pressure drops. The equations are solved numerically in a finite difference approximation coded for a digital computer. Two versions of the model exist; one where the total pressure drop over the channel is prescribed and one where the total pressure drop is calculated from the downcomer data.

An experimental study of the hydrodynamic instability and dynamic burnout in two-phase flow has been performed in a natural circulation loop in the pressure range from 10 to 70 atg. The test sections were round ducts of 20, 30, and 36 mm inner diameter and 4890 mm heated length. The experimental results showed that within the ranges tested, the stability of the flow increases with increasing pressure and increasing throttling before the test section, but decreases with increasing inlet sub-cooling and increasing throttling after the test section. Comparing the natural circulation burnout steam qualities with corresponding forced circulation data showed that the former data were low by a factor up to 2.5. However, by applying inlet throttling of the flow the burnout values approached and finally coincided with the forced circulation data.

The present experimental results as well as data available from other sources have been compared with the stability thresholds obtained with the theoretical model. The comparisons included circular, annular and rod cluster geometries, and the agreement between the experimental and theoretical stability limits was very good, the deviations being generally less than 10 per cent.

The application of the experimental and theoretical results on the assessment of boiling heavy water reactor design is discussed. It is shown qualitatively how hydrodynamic instability and burnout affect the optimization of the reactor performance.